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(54) Title: LIGHTWEIGHT AGGREGATE

(57) Abstract

The present invention relates to a lightweight aggregate in the form of pellets or granules and, in particular to a lightweight aggregate in the form of pellets or granules for use in the building industry. The present invention provides a method for forming a lightweight aggregate comprising mixing together from 80 % to 99 % by weight of pulverised fuel ash, from 1 % to 20 % by weight of cement and an amount of polystyrene beads having a particle size of less than 2.5 millimetres, such that the volume of polystyrene beads is from 15 % to 80 % of the total volume of the final mixture to form a pelletisable mix, forming the mix into pellets having a diameter of less than 15 millimetres and curing the pellets in a moist atmosphere at a temperature below the vapourising temperature of any solvent within the polystyrene beads.

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LIGHTWEIGHT AGGREGATE

The present invention relates to a lightweight aggregate in the form of pellets or granules and, in particular, to a lightweight aggregate in the form of pellets or granules for use in the building industry. The pellets of aggregate are suitable, for example, for making structural or non-structrual building blocks, for lightweight fill and as a filler for lightweight concrete, for example lightweight concrete screeds. This invention also importantly incorporates pulverized fuel ash, which is a waste product from coal-fired power stations.

It has previously been shown that the incorporation of expanded polystyrene beads in lightweight concrete, cement and plaster mixes can result in lightweight building materials.

JP-60176976 teaches the production of lightweight building material from mixtures of an inorganic binder, a lightweight aggregate such as polystyrene beads and reinforcing fibres.

GB-1118621A relates to cement or plaster mixes comprising cement or plaster, expanded polystyrene, filler and a suspending agent.

GB-2095227A teaches a method of making lightweight concrete comprising cement, expanded polystyrene, sand, water and a surfactant.

US-3764357A teaches the preparation of lightweight concrete and plaster by a method comprising several steps to ensure that the lightweight aggregate is uniformly mixed with the cementaceous material and other relatively heavy ingredients of the mixes.

GB-2100244A teaches the production of insulating building blocks comprising a cement, a filler and a

lightweight material, for example polystyrene, comprising up to 25% of the volume of the block.

It is also known to produce a lightweight aggregate in the form of pellets from pulverised fuel ash and a relatively small proportion of lime or cement, calculated on the content of fuel ash.

It has never previously, however, been considered feasible to incorporate large quantities of expanded polystyrene beads in such pellets because it has been thought that the presence of polystyrene would interfere with the pelletising or granulating process by preventing compaction of the fuel ash/cement mixture and that the polystyrene would migrate towards the surface of the pellets during formation thereof, so that the pellets would consist of a core of solid material and a soft surface layer mainly of polystyrene beads.

It has now been found that a lightweight aggregate containing large quantities of expanded polystyrene beads can be successfully produced.

Accordingly the present invention provides a method for forming a lightweight aggregate comprising mixing together from 80% to 99% by weight of pulverised fuel ash, from 1% to 20% by weight of cement and an amount of expanded polystyrene beads having a particle size of less than 2.5 millimetres, such that the volume of polystyrene beads is from 15% to 80% of the total volume of the final mixture, to form a pelletisable mix, forming the mix into pellets having a diameter of less than 15 millimetres and curing the pellets in a moist atmosphere at a temperture below the boiling point of any expanding agent within the polystyrene beads.

The preferred proportion of cement in the mixture is from 10% to 15% by weight, the preferred size of the polystyrene beads is less than 1 millimetre and

the preferred diameter of the pellets is from 3 to 9 millimetres. The minimum quantity of 1% by weight of cement is required to hold the pellet together.

The pellets are preferably cured at a temperature which is not above 50°C and hardened sufficiently in 1 to 2 days, depending on the curing temperature.

The rate of curing of the pellets can be increased if pulverised fuel ash, which retains heat from the power station in which it is produced, is utilized in the process.

Fuel ash which is preferred for use in the preparation of the lightweight aggregate of the present invention is produced as waste from coal fired power stations which burn hard coal, for example coal fired power stations found in the United Kingdom. The form of fuel ash preferred is either as dry ash or a sticky mix comprising approximately 12 to 15% water. Where the fuel ash for use in preparing the aggregate is already moist, for example in the form of a sticky mix, additional water to form a pelletisable mix may not be required. Where the fuel ash is used is in the form of dry ash or does not contain sufficient water to form a pelletisable mix, additional water is required during the mixing of the solid batch components and polystyrene beads. The cement used in the process is preferably Portland cement. The pulverised fuel ash used in the process is preferably fly ash.

It is also possible to add an inert filler in an amount of up to 20% by weight of the material forming the pellets (other than the polystyrene). Such fillers should be very fine material, preferably of particle size of less than 20 micrometres. Examples of such inert fillers are furnace bottom ash, ground slag, sand or finely ground quarry waste, such as rock dust.

If desired, after curing and hardening, the pellets may be heated to remove the exposed polystyrene beads on the surface of the pellets. Those polystyrene beads completely enclosed within the pellets begin to melt at approximately 300°C. The hardened pellets are strong enough to withstand the internal forces produced by any further expansion of the polystyrene beads on such heating. Such "burnt out" pellets which have had the exposed polystyrene beads removed from the surface thereof have increased densities and may also have increased thermal properties.

It may be that "burnt out" pellets which have had the polystyrene beads removed from the surface thereof are more popular in the building industry than those pellets where the polystyrene beads remain.

A further embodiment of the present invention is a method of preparing a lightweight aggregate wherein up to 15% by weight of liquid of powdered fuel is used to replace the same amount of cement in the mixture. Pellets which have been prepared with the inclusion of liquid or powdered fuel are hardened by sintering at a temperature in the range of from 800°C to 1400°C. This heating further increases the porosity of the pellets by burning out the combustable (organic) components of the pellets. At these temperatures, the moisture in the polystyrene beads contained within the pellets vaporizes and forms voids, the silica within the pulverized fuel ash melts, vitrifies and on cooling forms a coating around the pellet. During the preparation of any embodiment of the present invention from 1 to 6% by weight of hydrated lime may be used to replace the same amount of cement in the mixture.

The pelletisable mix according to the present invention is preferably made by weighing out the desired quantities of fuel ash and cement, or fuel

ash, liquid or powdered fuel and cement, measuring out the desired relative volume of polystyrene beads, wetting the surface of the beads and coating the wetted beads with a small amount of at least one of the weighed components prior to mixing the beads with the remainder of the weighed components. Wetting the beads encourages the pulverized fuel ash and/or other components of the mix to stick to the polystyrene beads and destroys the electrostatic properties of the beads. Only a proportion of the total water needed is required to wet the beads initially.

Pretreatment of the polystyrene beads with surfactants or other surface treating agents may be necessary to aid compatibility with the other ingredients of the pellets. The pellets are preferably formed on a pan pelletiser with a water spray, if additional water is required.

The pellets produced according to the present invention have a bulk dry density in the range of from 200 to 750 kilograms per cubic metre. Those pellets with a bulk dry density of 300 kilograms per cubic metre, or below, are suitable for use in preparing thermal building blocks and those pellets with a bulk dry density of 400 kilograms per cubic metre or above may be used to prepare "standard" building blocks.

The pellets produced according to any embodiment of the invention may be used for the manufacture of building blocks by adding them to a matrix and moulding them in the standard fashion. The preferred matrix mix is formed from cement, pulverized fly ash and water. Building blocks prepared with the pellets of the present invention have performances closely approaching those of aerated concrete blocks.

As used herein, the term "thermal building block" is intended to cover building blocks with a bulk dry density of 500 kilograms per cubic metre, or below and

the term "standard building block" is intended to cover building blocks with a bulk dry density of 600 kilograms per cubic metre, or above.

The present invention is further described by reference to the following Examples;

Example 1

A batch comprising 12.5% by weight of Portland cement and 87.5% by weight of fly ash was weighed out and the bulk volume of the batch assessed. For each 100 parts by volume of the batch 185 parts by volume of polystyrene beads of diameter less than 1 millimetre were measured out. The polystyrene beads were moistened with water and mixed with sufficient material taken randomly from the batch to produce a thin adherent coating on the beads. The remainder of the batch and a small amount of water was then added and mixing was continued to produce an intimate mixture of flyash, cement and polystyrene beads, the polystyrene beads comprising 65% by volume of the mixture.

The mixture was fed into a 1 metre pan pelletiser with a water spray. The angle of tilt of the pan, the pan speed and depth and the water spray were adjusted until the pellets leaving the pan were hard enough to withstand handling and the major proportion were in the size range 3 to 9 millimetres.

The pellets were passed to storage in a high moisture atmosphere and allowed to hardened at ambient temparature for two days.

The hardened pellets had a bulk density of 450 to 550 kg/m^3 and an average crushing strength in excess of $150N/cm^2$ as measured on a Schleuniger tablet test machine between filter paper linings to avoid point loading on the pellets.

A batch of the pellets was mixed with 20% weight of a 4:1 fly ash/cement mixture, sufficient water

added to achieve workability and formed into standard 100 mm building blocks. The blocks had an average density of 640 kg/m^3, a crushing strength of at least 2.8N/cm^2 and a thermal conductivity of 0.15 W/m.K. measured according to BSS 874. Part 2, Section 2.1 (1986).

Example 2

Lightweight aggregates were prepared according to example 1 using waste pulverized fuel ash from different coal fired power station sources. The quantities of solid batch material and polystyrene beads were as follows;

A total of 500 ml of solid batch material and 1500 ml of polystyrene beads were used to prepare each aggregate.

The polystyrene beads comprised 75% by volume of the final mixture of each aggregate.

Table 1 shows the bulk densities of the aggregates prepared with the sources of pulverized fuel ash indicated.

Table 1

PFA Source	Bulk Density of aggregate Kg/m^3
Eggborough	255
West Burton	225
Blyth	235
Drax	300
Reference	
Drax [constitute PFA only]	900

The aggregates from Table 1 have bulk dry densities suitable for use in preparing thermal building blocks.

CLAIMS:

1. A method of making a lightweight aggregate comprising mixing together from 80% to 99% by weight of pulverized fuel ash, from 1% to 20% by weight of cement and an amount of expanded polystyrene beads having a particle size of less than 2.5 millimetres, such that the volume of polystyrene beads is from 15% to 80% of the total volume of the final mixture, to form a pelletisable mix, forming the mix into pellets having a diameter less than 15 millimetres and curing the pellets in a moist atmosphere at a temperature below the boiling point of any expanding agent within the polystyrene beads.

2. A method as claimed in claim 1 wherein the polystyrene beads have a particle size of less than 1 millimetre.

3. A method as claimed in claim 1 or claim 2 wherein the mix is formed into pellets having a diameter in the range of from 3 to 9 millimetres.

4. A method as claimed in any one of the preceding claims wherein prior to mixing with the solid components of the mix, the polystyrene beads are treated with a surfactant, another surface treating agents, or combinations of two or more thereof.

5. A method as claimed in any one of the preceding claims further including the addition of water to form the pelletisable mix.

6. A method as claimed in any one of the preceding claims wherein up to 20% by weight of the material (other than the pellets) is an inert filler.

7. A method as claimed in any one of the preceding claims wherein the pellets are formed using a pan pelletiser.

8. A method as claimed in any one of the preceding claims further including, after curing, heating the

pellets to temperatures above 250°C.

9. A method as claimed in any one of the preceding claims wherein up to 15% by weight of liquid or powdered fuel is used to replace the same amount of cement in the mixture.

10. A method as claimed in claim 6 further including sintering the pellets at a temperature in the range of from 800°C to 1400°.

11. A method as claimed in any one of the preceding claims wherein from 1 to 6% by weight of hydrated lime is used to replace the same amount of cement in the mixture.

12. A lightweight aggregate whenever prepared by a method as claimed in any one of claims 1 to 7.

13. A lightweight aggregate as claimed in claim 11 having a bulk dry density of from 200 to 750 kg/m^3.

14. A lightweight aggregate as claimed in claim 11 preferably having a bulk dry density of 300 kg/m^3 or below.

15. A building block whenever prepared from the lightweight aggregate as claimed in any one of claims 12 to 14.

16. A building block as claimed in claim 15 having a block density of 400 kg/m^3 or above.

INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 91/02157

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl. 5 C04B18/02; //(C04B18/02,16:08,18:08)

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
Int.Cl. 5	C04B

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched[8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category[10]	Citation of Document,[11] with indication, where appropriate, of the relevant passages[12]	Relevant to Claim No.[13]
X	DE,A,3 834 751 (M.ACKERMANN) 19 April 1990 see page 2, line 7 - line 14 see page 2, line 23 - line 53; claims 1-3,10	1,4,5, 12,13,15
A	CHEMICAL ABSTRACTS, vol. 106, no. 18, Columbus, Ohio, US; abstract no. 139224B, ZHIGALOV, V. G. ET AL.: 'Macrospheres as low-density filler for polymeric structural materials.' Plast. Massy (2), 64 (Russ) 1987 see abstract	1
A	DE,C,3 631 221 (H.J.KRAUSE) 11 February 1988 see the whole document	1,5,6,12
A	FR,A,2 631 331 (SOCIETE ROBERT) 17 November 1989 see claims	1,4

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* Special categories of cited documents :[10]

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
04 MARCH 1992	11. 03. 92
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	THEODORIDOU E.

Form PCT/ISA/210 (second sheet) (January 1985)

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category °	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
A	DE;A,1 803 381 (GEBR. RHODIUS) 21 May 1970 see page 4, paragraph 1 - page 5, paragraph 3; claims ---	1,3,5,6, 12-15

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO. GB 9102157 SA 54073

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on
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Patent document cited in search report	Publication date	Patent family member(s)		Publication date
DE-A-3834751	19-04-90	None		
DE-C-3631221	11-02-88	None		
FR-A-2631331	17-11-89	None		
DE-A-1803381	21-05-70	AT-A,B	308622	15-05-73
		AT-A,B	308621	15-05-73

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